ISSN 1990-3413, Astrophysical Bulletin, 2017, Vol. 72, No. 4, pp. 486–501. © Pleiades Publishing, Ltd., 2017.
Original Russian Text © A.N. Sarkisyan, A.S. Vinokurov, Yu.N. Solovieva, O.N. Sholukhova, A.E. Kostenkov, S.N. Fabrika, 2017, published in Astrofizicheskii Byulleten', 2017, Vol. 72, No. 4, pp. 527–543.

SPEXTRA: Optimal Extraction Code for Long-Slit Spectra in Crowded Fields

A. N. Sarkisyan[1*], A. S. Vinokurov[1], Yu. N. Solovieva[1], O. N. Sholukhova[1], A. E. Kostenkov[1,2], and S. N. Fabrika[1,3]

[1] *Special Astrophysical Observatory, Russian Academy of Sciences, Nizhnii Arkhyz, 369167 Russia*
[2] *Saint-Petersburg University, St. Petersburg, 199034 Russia*
[3] *Kazan (Volga region) Federal University, Kazan, 420008 Russia*

Received June 15, 2017; in final form, August 22, 2017

Abstract—We present a code for the optimal extraction of long-slit 2D spectra in crowded stellar fields. Its main advantage and difference from the existing spectrum extraction codes is the presence of a graphical user interface (GUI) and a convenient visualization system of data and extraction parameters. On the whole, the package is designed to study stars in crowded fields of nearby galaxies and star clusters in galaxies. Apart from the spectrum extraction for several stars which are closely located or superimposed, it allows the spectra of objects to be extracted with subtraction of superimposed nebulae of different shapes and different degrees of ionization. The package can also be used to study single stars in the case of a strong background. In the current version, the optimal extraction of 2D spectra with an aperture and the Gaussian function as PSF (point spread function) is proposed. In the future, the package will be supplemented with the possibility to build a PSF based on a Moffat function. We present the details of GUI, illustrate main features of the package, and show results of extraction of the several interesting spectra of objects from different telescopes.

DOI: 10.1134/S1990341317040137

Key words: *methods: data analysis—techniques: image processing*

1. INTRODUCTION

Spectroscopy is one of the key methods of the study of astrophysical objects. However, in many cases, reduction of spectral data is not an easy task. Objects of special interest to us such as LBV stars (Luminous Blue Variables), B[e] supergiants, and WR stars in nearby galaxies [1–4] are usually located in crowded fields. Under these circumstances, several stars may fall into the spectrograph slit at a distance of several arcseconds from each other, and the magnitudes of the objects under study most often do not exceed 18^{m}. In crowded stellar fields, especially in galaxies with high star-formation rate, almost always there are H II regions. Stars are often surrounded by nebulae and are observed against the background of a galaxy, while the background can be about 20 mag per one square arcsecond. It is important that an early-type star itself can form a nebula. LBV stars, WR stars, and OB stars in young star clusters, X-ray sources, and ultraluminous X-ray sources (ULXs) almost always form surrounding nebulae. Such nebulae can be of an asymmetric shape or, depending on the degree of ionization of surrounding gas, lines (e.g., hydrogen lines, O[III] $\lambda\lambda 4959, 5007$, He II $\lambda 4685$, numerous He I, N[II] $\lambda\lambda 6548, 6583$, and S[II] $\lambda\lambda 6716, 6730$ lines) can be of different intensity in different directions. For the most complete and reliable analysis of the observed data in all these cases, an appropriate reduction procedure is necessary.

The method of the optimal extraction of spectra of single objects which provides the maximum S/N ratio was proposed by K. Horne in 1986 [5]. The method is based on the principle of using weighted summation with account of the fraction of useful (belonging to an object) signals instead of simple summation of signals while using aperture extraction. This can be done knowing the spatial profile of an object. In this case, as shown in the above paper, the weighted summation procedure with respect to the profile is equivalent to its fitting to a 2D spectrum. Variations of the method [5] are generally in the ways of determination of the spatial profile of an object. There are two main approaches: determination of the profile from spacial slices of the spectrum itself or applying of the analytical profile. The first method is

*E-mail: ars@sao.ru